CHAPTER 4

SITE DEVELOPMENT

INDEX

EXHIBITS

CHAPTER 4

SITE DEVELOPMENT

4.1 GENERAL.

4.1.1 Scope.

This chapter states criteria, requirements and guidance for civil design. The design shall be accomplished in accordance with appropriate manuals and pamphlets and with basic criteria furnished in Statment of Work.

4.1.2 Quality of Design.

It is the purpose of the COE to obtain excellent siting and civil design resulting in efficient and economical paving, grading and drainage conditions.

4.2 APPLICABLE PUBLICATIONS.

Army Design Criteria — AEI (Architectural and Engineering Instructions),

Air Force Construction — AFR 88-15 Criteria and Standards for Air Force

Uniform Federal Accessibility Standards

EM 1110-2-410	Design of Recreation Areas and Facilities, Access and Circulation
TM 5-803-5	Installation Design
TM 5-820-4	Drainage and Erosion Control - Drainage for Areas other than Airfields
TM 5-822-2	General Provisions and Geometric Design for Roads, Streets, Walks and Open Storage Areas
EIRS Bulletin 81-05	Dimensions for Typical POV Parking Areas
TM 5-822-5	Pavement Design For Roads Streets, Walks, and Open Storage Areas.
TM 5-822-7	Standard Practice for Concrete Pavements
TM 5-822-8	Bituminous Pavements - Standard Practice

4.3 PROJECT DEFINITION (10-15%).

The Designer shall develop a conceptual site plan which encapulates the project requirements. The plan should be an efficient layout with emphasis given to user requirements. The plan shall show building locations, parking areas, roads, and pedestrian access points. The plan shall be developed so that a preliminary cost estimate can be prepared.

4.4 CONCEPT DESIGN REQUIREMENTS (30-35%).

4.4.1 Concept Design Analysis.

Provide information concerning the following, as applicable:

4.4.1.1 General.

(a) Project location and access to the site.

(b) Explanation of objectives and factors influencing siting.

(c) General overview of major site features planned, such as building orientation, drainage patterns, parking provisions, traffic circulation, provisions for the handicapped, security requirements, etc.

(d) Impact of new construction on existing facilities.

(e) Considerations for future expansion.

(f) Existing site features including general topography, acreage, boundaries, etc.

(g) Unusual subgrade conditions.

(h) Former use of the site.

(i) Requirements for flood protection.

(j) Locations of borrow and spoil areas.

4.4.1.2 Removals.

(a) Specific items requiring removal or relocation.

(b) Disposition of waste or salvage materials.

4.4.1.3 Geometry.

(a) Rationale for locating major site elements.

(b) Set back requirements or specific clearance requirements.

4.4.1.4 Storm Drainage.

(a) Selected storm drainage plan with respect to existing storm drainage system.

(b) Alternate schemes considered in arriving at selected plan.

(c) Considerations for future expansion and change in land use within the watershed.

(d) Principal means of storm water collection.

(e) Disposition of storm water collected in the new system.

(f) Planned connections to the existing storm drainage system.

(g) Handling of roof runoff.

(h) Connections of building mechanical drains to outside drainage system.

(i) Selected design values to be used in the storm drainage calculations such as surface runoff coefficient, retardance coefficients, infiltration rate, and rainfall intensity based on a 10-year storm frequency, unless otherwise instructed.

(j) Easement requirements.

(k) Discussion of the need for a stormwater discharge permit and to whom the permit shall be sent.

4.4.1.5 Grading.

(a) Existing site features affecting grading such as buildings, streets, curbs, walks, fences, water courses, ponds, elevation of high water, rock outcrop, etc.

(b) Design flood frequency and minimum elevation to provide flood protection (if applicable).

(c) Planned finished floor elevation.

(d) Cut or fill requirements and rough estimate of quantities.

4.4.1.6 Pavement Design.

(a) General soil conditions.

(b) Vehicular Pavements Thickness Design.

(1) Specific design values for which pavement thickness is based including the number, type, and maximum weights of vehicles, category of traffic, class road or street, and resulting design index.

(2) Flexible Pavements-required thickness of base and pavement (7-1/2 inch (19cm) minimum) based on the design index and established subgrade CBR.

(3) Rigid Pavements-required thickness of nonreinforced concrete pavement (6-inch (15cm) minimum) based on a 28-day flexural strength concrete of 650 psi and the established modulus of subgrade reaction.

(c) Aircraft Pavement Thickness Design. All airfield pavement structures and materials specification shall be prepared by Design and

Review Section EN-DR of the Mobile District Corps of Engineers. (This information shall be provided to the A-E if the project is being designed under contract.)

(1) Flexible Pavements-specific design values for which pavement thickness is based including the airfield class, type traffic area, gross weight of aircraft, number of passes, subgrade CBR, and resulting minimum thickness of base and pavement.

(2) Rigid Pavements-specific design values for which the pavement thickness is based including the type of aircraft gear, gear design load, modulus of subgrade reaction or resultant modulus of both subgrade and base course, flexural strength of concrete, and resulting pavement thickness.

(3) For project requiring airfield pavement, the designer (EN-DR) shall coordinate with Geotechnical Branch, Geotechnical and Dam Safety Section (EN-GG), for required material investigations and specificaton requirements. Notification of the proposed pavements should be given EN-GG as soon as possible so as to allow time for any needed sampling.

4.4.1.7 Roads.

(a) Traffic volume and type.

(b) Particular AASHTO design vehicle for which turning movements are to be provided for and corresponding minimum turning radius.

(c) Design speed.

(d) Maximum degree of curvature and control grades.

(e) Sight distance requirements.

(f) Lane and shoulder widths.

(g) Cross slopes for lanes and shoulders.

(h) Embankment slopes.

(i) Requirements for curbs, sidewalks, guardrails, traffic signs and markings, fencing, etc.

(j) Rights-of-way and easements.

4.4.1.8 Parking and Open Storage Areas.

(a) Type vehicles to be accommodated.

(b) Size of individual parking spaces and number to be provided.

(c) Number and location of handicapped parking spaces.

(d) General location of parking or storage areas.

(e) Location of ingress and egress.

(f) Pedestrian access.

(g) Use of 90°, 60°, or 45° parking and relation to traffic operation.

4.4.1.9 Miscellaneous Site Features.

(a) Curbs, and curbs and gutters--types and locations.

(b) Sidewalks-- width, and locations.

(c) Fencing--justification, type, size and location of gates.

4.4.1.10 Railroads.

(a) Type of service for which track shall be provided.

(b) Anticipated volume.

(c) Maximum grade and degree of curvature.

(d) Features of track construction such as thickness and type of ballast, weight of rail, dimension of ties, size of turnouts, etc.

(e) Special requirements for track scales, bumpers, signals, grade crossings, derailers, etc.

4.4.1.11 Outline Specifications.

List all Corps of Engineers Guide Specifications.

4.4.1.12 Additional Information.

List additional information or criteria needed for design.

4.4.2 Concept Drawings.

Provide the following.

4.4.2.1 Location and Vicinity Maps.

Indicate project site, borrow and spoil areas, haul routes, and contractor's access to the site. Drawing to be complete for 35% submittal.

4.4.2.2 Site Plan (Geometry).

(a) Provide an overall site plan showing total development.

(b) Show the proposed geometry of the site plan using a minimum scale of l" = 30'(1:500), unless otherwise directed. Include the existing topography without contours that shall remain after construction.

(c) Use graphic symbols to distinguish new and existing site work, and provide legand to define graphic symbols.

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(d) Provide sufficient geometric information to adequately locate all new major site elements.

(e) Identify the grid state system used. Include a north arrow.

4.4.2.3 Grading and Drainage Plan.

(a) Show the complete drainage concept using either finished contours or slope arrows and estimate storm drain pipe sizes.

(b) Use a minimum scale of l" = 30' (1:500), unless otherwise directed.

(c) Show and identify all existing buildings and facilities on plan.

(d) Show the proposed finished floor elevation and critical spot elevations.

(e) Locate bench marks, list horizontal and vertical data for each.

(f) Reflect existing utilities with the topography. If necessary for clarity, show removals, relocations, and new work for utilities on separate plans.

(g) All contour intervals shall be 1 foot (25cm), unless otherwise directed.

4.5 INTERIM DESIGN (50-60%).

Advance from concepts into design. Comply with comments from the concept review.

4.5.1 Preliminary Design Analysis.

Update and expand the Concept Design Analysis to support the submittal and include the following, as applicable:

4.5.1.1 Storm Drainage Design.

(a) Complete storm drainage design calculations consistent with the requirements of the applicable TMs and based on the design values established in the Concept Design Analysis.

(b) Provide a map outlining drainage areas affecting new construction.

(c) Use the General Instructions Relative for the Design of Storm Drainage Systems for Other Than Airfields based on TM 5-820-4. See paragraph 4.8 below.

(d) Provide complete calculations for sizing retention and/or detention ponds.

(e) Identify any State or local requirements with which the storm drainage design must comply.

(f) Provide watertight joints for drainage pipe under all pavements (aircraft and vehicular) when the pipe is placed in a noncohesive soil (see TM 5-820-4, paragraph 2-06j).

(g) Contour intervals should be 1 foot (25cm), unless otherwise directed.

4.5.1.2 Pavement Design.

(a) Complete flexible and rigid pavement design calculations consistent with the requirements of the applicable TM's and based on the various design values in the Concept Design Analysis.

(b) Present complete calculations for pavement options to be allowed.

(c) Describe the nature of the materials to be used in pavement structure and their thickness.

(d) Describe the minimum compaction requirements.

4.5.1.3 Additional Information.

List additional information or criteria needed for final design.

4.5.2 Preliminary Drawings.

Although it is intended that major items of work be shown separately, different items may be shown on the same sheet provided that the presentation is sufficiently clear to permit legible reproduction at half-scale.

4.5.2.1 Location and Vicinity Maps.

(Previously completed for the Concept Design submittal.)

4.5.2.2 Removal and/or Relocation Plan.

Indicate all items of site work which shall require removal or relocation.

4.5.2.3 Site Plan (Geometry).

(a) Complete a geometric layout of all items of new work using offset dimensions from existing structures or, if necessary, use coordinates for locating new work.

(b) Include in the plan information on specific items of work.

(c) Indicate soil boring locations and designations.

(d) Complete the legend to include all items and symbols shown on the plans. Symbols should be consistent between successive drawings.

4.5.2.4 Grading and Drainage Plan.

(a) Indicate all items of work superimposed on the existing topography.

(b) Indicate the proposed contours for new grading and provide spot elevations as required to facilitate field layout. All contour intervals should be 1 foot (25cm), unless otherwise directed .

(c) Layout the new storm drainage system using the symbols covered in the legend.

(d) Identify drainage structures with number designations corresponding to those used in the storm drainage schedule to be included in the drawings.

(e) Indicate the finished floor elevations of new buildings.

(f) Locate or make reference to monuments and bench marks for horizontal and vertical control.

(g) Unless otherwise directed, provide profiles for all storm drains and culverts. Indicate top and flow line elevations of all drainage structures, storm drain pipe with size and invert elevations, ground profile, and new or existing structures or utilities crossing the new storm drain.

4.5.2.5 Plan and Profile Sheets.

(a) Show on the plan the construction centerline, right-of-way limits, and all important topographical features such as fences, buildings, streams, railroads, etc.

(b) Locate or make reference to monuments and bench marks for horizontal and vertical control.

(c) Provide complete survey information necessary for establishment of the survey centerline including computed bearings of all tangents, curve data, superelevation requirements, coordinates of point of beginning, point of ending, all P.I.s, etc.

(d) When superelevation is required, include on the plan a diagrammatic profile of how the superelevation is obtained and also a table of shoulder slopes versus cross slopes for the superelevated section.

(e) Note on the plans the size and type of all existing structures and the manner in which they are to be utilized or removed, or otherwise affected by new work.

(f) Plot the centerline profile on the profile portion of the sheet at the same horizontal scale as the plan. Normally, use a vertical scale of 1″ = 5′ (1:50), or as appropriate to terrain.

(g) Provide elevations at points where changes of grade occur.

(h) Indicate the lengths of vertical curves.

(i) Indicate the existing ground line at centerline on the profile.

(j) Indicate the percentage of slope for all grade lines. Provide special information pertaining to the profile and affecting the design such as curb grades, gutter grades, drainage structures inverts and top elevations, etc.

(k) Provide centerline grade elevations at each 50-foot (15M) station. In vertical curves.

(l) Show new and existing drainage structures on the profile.

4.5.2.6 Miscellaneous Details.

Plans shall include the following, as applicable:

(a) Typical pavement sections.

(b) Minimum paving and compaction requirements.

(c) Typical sections through the site as required for clarity.

(d) Legend.

(e) Concrete joint layout.

(f) Concrete joint details.

(g) Sidewalk joint layout.

(h) Storm drainage pipe and structure schedule.

(i) Parking layout.

(j) Superelevation and widening details.

4.6 FINAL DESIGN (UNREVIEWED 100%).

Advance design to completion complying with comments from the Preliminary Review.

4.6.1 Final Design Analysis.

Update previously-prepared analysis to support final plans and specifications.

4.6.2 Final Drawings.

(a) Add general notes to drawings as required.

(b) Insure correct cross referencing among site drawings for appropriate details, sections, match lines, etc.

(c) Eliminate all conflicts (horizontal and vertical) among site plans and architectural, structural, and utilities plans.

4.6.3 Final Specifications.

(a) Complete draft of specifications to cover all items of site work.

(b) Insure consistency of terminology between plans and specifications for notations on specific items of work.

(c) Perform check to insure adequate referencing for construction details.

4.7 READY-TO-ADVERTISE SUBMITTAL REQUIREMENTS (l00%).

4.7.1 Final Design Analysis.

Complete analysis supporting the requirements of the project.

4.7.2 Final Design Drawing.

Complete thoroughly checked drawings and specifications, with all comments from the final revier incorporated.

4.8 GENERAL INSTRUCTIONS RELATIVE TO DESIGN OF STORM DRAINAGE SYSTEMS FOR OTHER THAN AIRFIELDS.

4.8.1 References.

(a) TM 5-820-4, Drainage for Areas Other Than Airfields.

(b) Design compilation sheets (4 total).

(c) Sample "Storm Drainage Pipe and Structure Schedule" (To be included on the Plans as appropriate).

4.8.2 General.

For the design of other than airfield storm drainage systems, the procedure which follows and, as appropriate, TM 5-820-4 shall be utilized. Design compilation sheets, reference l.c., shall be used during the design and included as a part of the design analysis. The design analysis shall also include an overall drainage map depicting individual drainage areas, assumed paths, and slopes of runoff used to compute times of concentration, and the types of surface within the individual areas.

(a) For projects located in the states that require storm water permits,the designer shall the perform the drainage design in accordance with the state's criteria. A complete record of the criteria and calculations shall be maintained by the designer.

4.8.3 Notes To Designer.

(a) The "Procedure for Design of Storm Drainage Systems for Other Than Airfields" was developed to consolidate and clarify design criteria and procedures presented in TM 5-820-1 and TM 5-820-4, to facilitate designs of other than airfield drainage systems, and to achieve design consistency.

(b) This design procedure in no way relieves designers of their responsibility to comply with the provisions and requirements of TM 5-820-4.

(c) The storm runoff design procedure presented in Steps l through l2 in 4.8.5 applies to both the closed storm drainage system and individual culverts. The pipe sizing procedure presented in Steps l3 through l9 applies to closed storm drainage systems only. Individual culverts shall be sized using procedures contained in TM 5-820-4.

4.8.4 Drainage Design Criteria.

(a) The criteria and procedures are for areas up to one square mile, where only peak discharges are required for design, and ponding is not permitted.

(b) The design storm shall be based on l0-year storm frequency.

(c) Minimum times of concentration, t_c, of l0 minutes for paved areas and 20 minutes for grassed areas shall be used.

(d) Manholes or junction boxes shall be provided at points of change in conduit grade or size, at junctions with laterals or branches, and wherever entry for maintenance is required. Distance between points of entry shall be not more than about 300 feet for conduits with diameter smaller than 30 inches. Conduit alignment between entry points shall be straight, except for 30 inches and larger sizes.

(e) Pipe discharge velocities must not be less than 2.5 fps to provide for adequate pipe cleansing.

(f) Minimum pipe sizes shall be l2 inches for closed drainage systems and l8 inches for individual culverts, unless unusual or special design considerations warrant using smaller pipe.

(g) Storm drainage systems shall be constructed in accordance with specifications Section CE 02720. The specifications contain instructions and information which must be considered during design.

4.8.5 <u>Procedure For Design Of Storm Drainage Systems For Ohter Airfields</u>.

<u>Step 1</u> - Columns l through l4 of Table "A" of Exh. 4-1 show data necessary fordrain inlet design. The drainage area for each inlet is calculated with respect to the paved, bare soil and turfed surface conditions within the area. These areas are entered in Columns 2, 3, and 4. The total drainage area for each inlet is then entered in Column 5. Surface runoff coefficients "C" are assigned from Figure II of Exh. 4-3 based on the predominant paved, bare soil, and turfed surface conditions encountered in the overall drainage area and are entered at the top of Columns 2, 3, and 4. Only under unusual circumstances shall bare surface areas be considered in the drainage calculations. The weighted coefficient "C" for inlet number 1 is calculated as follows:

$$\frac{{}^{A}\text{Paved}\ ({}^{C}\text{Paved}) + {}^{A}\text{Turf}\ ({}^{C}\text{Turf})}{{}^{A}\text{Total}} = \frac{0.06\ (0.90) + 1.83\ (0.40)}{1.89} = \underline{0.42}$$

<u>Step 2</u> - The actual length of runoff "L" for each inlet or design point is scaled from contour maps, etc., with respect to the paved, bare soil and turfed surface conditions encountered. The sum of the individual lengths involved is entered in Column 7. Considerations must be given to the type of flow (sheet, channelized, ditch, swale, etc.), slopes, (along the flow path), and surface retardence coefficients when selecting the runoff length. Sheet flow is assumed to become channelized flow on unpaved surfaces after a sheet flow distance of 200 feet. The selected length of runoff should represent a realistic path of flow measured perpendicular to contours and one that shall provide the maximum runoff flow time (time of concentration). The actual runoff length "L" for inlet number 1 drainage area was determined to be 260 feet. The first 200 feet occurred with sheet flow on an average grass surface

sloping at 0.70%. The next 35' occurred with channelized flow on an average grass surface sloping at 0.70%. The assumed surface retardence "n" was 0.40 for sheet flow and 0.20 for channelized flow. The remaining 25 feet of runoff occurred on an asphalt paved surface sloping at 0.50% and having a retardence "n" of 0.02. Retardence "n" is the term used to designate the resistance to sheet, channelized, and ditch flow caused by various surface conditions such as vegetation, surface and alignment in the path of flow. Retardence coefficients are assigned from Figure III of Exh. 4-3. The average retardence "n" for inlet number 1 is calculated as follows:

$$\frac{{}^{L}\text{Surface 1 } ({}^{n}\text{Surface 1}) + {}^{L}\text{Surface 2 } ({}^{n}\text{Surface 2})}{{}^{L}\text{Total}} = \frac{200\ (0.4) + 35\ (0.20) + 25}{260}$$

enter in Column 8.

The average slope "S" for inlet number l is calculated as follows:

$$\frac{{}^{L}\text{Surface l } ({}^{S}\text{Surface l}) + {}^{L}\text{Surface 2 } ({}^{S}\text{rface 2})}{{}^{L}\text{Total}} = \frac{235\ (0.7) + 25\ (0.5)}{260} =$$

enter in Column 9.

Equivalent length "L_E" is now calculated using Formula I:

$L_E = 2.5\ Ln/\ \ s$

where L_E = equivalent length in feet for n = 0.4 and 5 = l%
L = actual measured distance of flow path in feet
n = average retardence coefficient
S = average slope in percent of flow path

For inlet number l, L_E is calculated as follows:

$$L_E = \frac{2.5\ (260)\ (0.34)}{0.68} = 268', \text{ enter in Column l0}$$

Step 3 - The time required for surface runoff to reach an inlet or design point when traveling along the previously-determined flow path is the time of concentration "t_c" The time of concentration for each inlet or design pointg is obtained from Figure V of Exh. 4-4 using equivalent lengths of runoff "L_E" from Column 10. The time concentration for inlet number 1 was determined from Figure V to be 22.1 minutes using the equivalent length of runoff "L_E" value of 268 feet. The 22.1 figure is rounded to 22 minutes and entered in Column 11.

Step 4 - Select a design storm index from Figure I of Exh. 4-2, based upon the location of the project, and enter at the top of Table A of Exh. 4-1. For this example, the project is located in Columbus, Mississippi, which yields a design storm index of 2.6 in./hr.

Step 5 - Using Figure VI of Exh. 4-5 for inlet number 1, enter the chart from the left using t_c" = 22 min. from Column 11 and read rainfall intensity under design storm index 2.6 as 4.60 in./hr. Enter in Column 12.

Step 6 - Infiltration "F" is the term used to refer to the absorption of rainfall by the ground during a design storm following a rainfall of one hour. Infiltration rates are assigned from Figure IV of Exh. 4-5 according to the predominant type of soil and ground cover encountered in the overall drainage area, and are shown at the tops of Columns 2, 3, 8, and 4. The weighted infiltration "F" for inlet number 1 is calculated as follows:

$$\frac{0.06\ (0.0) + 1.83\ (0.5)}{1.89} = 0.48, \text{ enter in Column 13.}$$

Step 7 - The Rational Method for computing runoff is Q = CA(i-F) where,

Q = runoff in cubic feet/sec
C = surface runoff coefficient
A = area (acres)
i = intensity (in./hr.)
F = infiltration rate (in./hr.)

The runoff for inlet number l is calculated as follows:

Q = 0.42 (l.89) (4.60 - 0.48) = 3.3 cfs.

Enter 3.3 cfs in Column l4. It is essential at this point to check the capacity of inlet No. l. All inlets, etc., must be sized to accommodate the design storm runoff without ponding.

Step 8 - Columns 15 through 28 of Table "B" Exh. 4-1 show data necessary to calculate rate of inflow into drains. Enter in Column 17 distance between inlets. Enter in Column 18 the areas calculated and shown in Column 5 of Table "A". Accumulate areas as each contributes to the entire system and enter in Column 19. The weighted runoff coefficient "C" for drain 2-3 is calculated as follows:

$$\frac{1.89\ (0.42) + 1.72\ (0.57)}{3.61} = 4.49$$

Enter in Column 20.

The weighted runoff coefficient for drain 5-6 is calculated as follows:

$$\frac{5.33\ (0.46) + 2.07\ (0.40) + 1.21\ (0.60)}{8.61} = 0.47$$

Enter in Column 20.

Step 9 - As runoff accumulates and increases in its passage through the system, the increase in runoff is not the summation of the peak runoff of each individual area, but is an increase modified by various factors. The major factor is the decreasing intensity of the storm effect on the lower areas due to the increasing time of concentration. To attain the maximum rate of runoff at a given point, the storm must continue long enough to profuce the maximum rate of inflow into each upstream drain inlet and to permit the inflow to travel through the drain from the "critical inlet" to the given point.

The "critical inlet" is the inlet whose drainage area requires the longest time of concentration within the pipe system being considered. The "critical inlet" and its time of concentration "t_c" are determined from Column 11 of Table "A" and entered respectively in Columns 21. and 22. Pipe flow time from the "critical inlet" to the given point is referred to as "drain time" "t_d". Drain time is comnputed using an assumed average pipe velocity of 6 f.p.s. and entered in Columan 23 for individual pipe runs. The drain time, "t_d", from the "critical inlet" to the given point is accumulated in Column 24. The critical time of concentration, "t_c", for the individual pipe run design, is calculated by adding "t_c" for the critical inlet from Column 22 to the accumulated drain time "t_d" from Column 24. The sum of the two, rounded to the nearest minute, is entered in Column 25.

Step 10 - With the time of concentration calculated in Column 25, storm intensity "i" for the drains can be derived as in Step 5, above, and entered in Column 26.

Step 11 - The weighted infiltration rate "F" for drain 2-3 is calculated as follows:

$\underline{1.89\ (0.48) + 1.72\ (0.33)} = 0.41$

Enter in Column 27.

Step 12 - The rate of inflow into the drains is calculated as in Step 7 above and entered in columns 28 and 32.

Step 13 - Columns 29 through 42 show data necessary for the design of storm drains. Pipe sizes, gradients, and velocities are determined on the basis of flowing full using Manning's equation ($Q = \underline{1.49} \times R^{2/3} \times S^{1/2} \times A$). All projects shall include designs for smooth interior and fully-paved c.m. pipe ("n" = 0.024). Nomographs shown in Figures VII may be used for the design of circular pipe having respective "n" values of 0.012 and 0.024. On occasion when non-circular pipe and/or pipe having other"n" values are required, they shall be designed using the Manning's Equation. Hydraulic Design Series No. 3 of "Design Charts for Open-Channel Flow" published by the U. S. Department fo Transportation, Federal Highway Administration (Reprinted 1979) is an acceptable design aid which may be used to design for these special conditions. Pipe roughness coefficients "n" for various pipe are shown in Figure X of Exh. 4.7.

Step 14 - The pipe roughness coefficient "n" is entered in the approrpiate space of the top of Table "C" of Exh. 4-1. For this example, an "n" value of 0.012 is being used.

Step 15 - Enter Figure VII of Exh. 4-5 using the design discharge from Column 32. Select a pipe size such that a line drawn from the design discharge from Colume 32 through the selected pipe size intersects the slope and velocity lines at minimum values. Slopes for the required pipe size should be held to a minimum consistent with limitations imposed by cover requirements, proximity to other structures, and interference with other utilities. Also, pipe sizes and slopes should be selected such that flow velocities in successive pipes remain fairly constant. To avoid ponding at intake points (inlet, catch basins, etc.), pipe inverts and velocities must be established such to maintain the kinetic energy line (velocity head $\frac{V^2}{2g}$ plus the entrance loss, head $\frac{K V^2}{2g}$) at or below the top or gutter line elevation of the intake structures. In most cases, providing minimum pipe cover shall fulfill or exceed the velocity head plus entrance loss requirement. Both conditions, however, must be checked to ensure that ponding shall not occur.

In profile proceeding downstream, the crowns of pipes where sizes progressively increase shall be matched. Crowns of incoming laterals shall be matched to that of mainline. Additional lowering of an outgoing pipe shall be required to compensate for head loss within the junction structure.

Step 16 - For pipe 1-2, a Q of 3.3 cfs (from Column 32) is entered into Figure VII of Exh. 4-5. At a slope of 0.85%, a 12" pipe shall handle the design discharge with a reasonable velocity. A line drawn through the pipe size of 12" and a slope of 0.85%, intersects the discharge line at 3.5 cfs and the velocity line at 4.6 fps. This indicates the capacity of the pipe flowing full is 3.5 cfs at a velocity of 4.6 fps. Enter the selected pipe size and slope into Columns 33 and 34, respectively. It is now necessary to determine the Velocity in the pipe for the design Q of 3.3 cfs. Compute the ratio of the design discharge (3.3 cfs) to the flowing full discharge (3.5 cfs) as follows:

$$\frac{Q \text{ Design}}{Q \text{ Full}} = \frac{3.3}{3.5} = 0.94$$

Enter the bottom of Figure IX of Exh. 4-6 at 0.94 and project a vertical line intersecting trhe "Capacity" curve. Continue the line horizontally from this point intersecting the "Velocity" curve. The partial full to full flow velocity ratio(^{V}Design/^{V}Full) is interpreted as 1.135 by projecting a vertical line from the "Velocity" curve to the bottom of Figure IX of Exh.4-6. The partial full or Pipe 1-2 design velocity (^{V}Design) is found to be (4.6) (1.135) = 5.2 fps and is entered into Column 35.

Step 17 - Head losses at junction structures shall now be taken into account. A loss coefficient "K" shall be selected from Figure XI of Exh. 4-7, depending on the type of junction. The "K" which produces the largest head loss at the junction shall be selected. For pipe l-2 passing through inlet number 2, a "K" value of 0.20 is selected from Figure XI. The head loss is calculated as follows:

$$H_L = \frac{K V^2}{} = \frac{0.20(5.2^2)}{} = 0.08'$$

2 g 2(32.2)

and is entered in Column 37.

This value is the amount of lowering required below the entrance invert of pipe l-2 for pipe 2-3 as it exits inlet number 2 to compensate for head loss through inlet. This lowering is in addition to any lowering required due to change in pipe size.

Step 18 - For each junction structure, the finished grade at the structure shall be determined and entered in Column 40.

The upper and lower inverts of each pipe are then calculated and entered in Columns 38 and 39, respectively. Actual depths of cover are calculated for each pipe and entered in either Column 41 or 42, whichever is applicable. Inverts shall be set so as to maintain the cover requirements specified in Tables II-1 through II-9 of TM 5-820-4 for pipe located under traffic areas and/or high fills. The minimum cover for reinforced concrete Class III or corrugated metal pipe is l.0 foot for Civil Works Recreation and Public Use projects. In non-traffic areas, l.0 foot minimum cover is required.

Step 19 - Maximum permissible outfall velocities for non-erosive flow are given in Table 9-l of TM 5-820-3. Pipe 5-6 outfalls into an existing silty-clay bare soil ditch, which permits a maximum non-erodable velocity of 3.5 fps (from Table 9-l). The discharge velocity in pipe 5-6 is 6.4 fps; therefore, energy dissipation, erosion protection and/or discharge velocity reduction (increase pipe size and/or reduce pipe slope) is required to prevent erosion of the outfall ditch.

A good design shall require analysis of several feasible alternatives to determine the most economical method of controlling erosion.

4.8.6 Bibliography.

(a) Figure I adopted from TM 5-820-1, Figure 1, dated April l977.

(b) Figures II, III, and IV from U.S. Army Engineer School - Engineer subcourse 359-3, Edition 3 (July l973), Tables 2-2, 2-1, and 2A-2 respectively.

(c) Figure V derived from average values taken from Figures 10 through l7, TM 5-820-1, dated April l977.

(d) Figure VI derived from Figure 2, TM 5-820-l, dated April l977.

(e) Formula I from U.S. Army Engineer School - Engineer Subcourse 359-3, Edition 3 (July l973), page 2 A-15.

(f) Figures VII and VIII were taken from TM 5-820-l, Figures 25 and 27, respectively, dated April l977.

(g) Figures IX was taken from TM 5-820-4, Figure l0, dated July l965.

(h) Figure X was taken from TM 5-820-3, Table 2-1, dated Jan. 1978.

(i) Figure XI was derived from "Handbook of Hydraulics," fifth edition by King and Brater.

DESIGN STORM INDEX 2.6IN/HR (FIG. I)
Q=CA(I−F) DESIGN STORM 10 YEARS
C=SURFACE RUNOFF COEFFICIENT I=INTENSITY
A=AREA (ACRES) F=INFILTRATION RATE

TABLE "A" DRAINAGE
DRAIN INLET CAPACITIES
(OTHER THAN AIRFIELDS)

DATE: 10JULY 75 | SHEET 1 OF 3
PROJECT: COLUMBUS L & D
LOCATION: COLUMBUS, MS
DESIGNED BY:W.D.P. | CHECKED BY: R.N.S.

INLET NUMBER	DRAINAGE AREA (ACRES) PAVED C=0.90 F=0.00	UNPAVED BARE C=0.60 F=0.20	UNPAVED GRASSED C=0.40 F=0.50	TOTAL AREA (COL 2+ COL 3+ COL.4)	WEIGHTED "C"	EQUIVALENT LENGTH "LE": ACTUAL LENGTH "L" (FT)	AVG RETARD-ENCE "n"	AVG SLOPE "S" %	EQUIV. LENGTH "LE" (FT)	DRAIN INLET CAPACITY: CRITICAL TIME Tc (FIG. V) (MIN)	STORM INTENSITY "I" (FIGVI)	WEIGHTED "F"	RATE OF SUPPLY "Q" (CFS)
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.06	–	1.83	1.89	0.42	260	0.34	0.68	268	22	4.60	0.48	3.3
2	0.57	–	1.15	1.72	0.57	185	0.33	0.50	216	20	4.75	0.33	4.3
3	–	–	1.72	1.72	0.40	190	0.80	3.00	219	20	4.75	0.50	2.9
4	–	–	2.07	2.07	0.40	285	0.34	0.60	313	24	4.40	0.50	3.2
5	–	1.21	–	1.21	0.60	165	0.10	0.25	83	13	5.70	0.20	4.0

TABLE "B" DRAINAGE
UNDERGROUND STORM DRAINS
(OTHER THEN AIRFIELDS)

DATE: 10JULY 79 | SHEET 2 OF 3
PROJECT: COLUMBUS L & D
LOCATIONS: COLUMBUS, MS
DESIGNED BY:W.D.P. | CHECKED BY: R.N.S.

DESIGN POINT: FROM INLET OR JUNCTION NUMBER	DESIGN POINT: TO INLET OR JUNCTION NUMBER	LENGTH (FT)	DRAINAGE AREA: INDIVIDUAL AREA (ACRES) (COL.5)	DRAINAGE AREA: ACCUM. TOTAL (ACRES)	WEIGHTED "C"	CRITICAL RUNOFF TIME TO PRODUCE MAX. FLOW IN DRAIN: CRITICAL INLET NUMBER	CRITICAL INLET TIME Tc(MIN) (COL 11)	DRAIN TIME Tc: ASSUME PIPE VEL. 6 FPS (MIN)	DRAIN TIME Tc: ACCUM. TOTAL (MIN)	CRITICAL PIPE TIME Tc(MIN) (COL 22+ (COL 24)	STORM INTENSITY "I" (FIG.VI)	WEIGHTED "F"	RATE OF INFLOW INTO DRAINS (CFS)
15	16	17	18	19	20	21	22	23	24	25	26	27	28
1	2	170	1.89	1.89	0.42	1	22	–	–	22	4.00	0.48	3.3
2	3	240	1.72	3.61	0.49	1	22	0.5	0.5	23	4.50	0.41	6.6
3	5	200	1.72	5.33	0.46	1	22	0.7	1.2	23	4.50	0.44	10.0
4	5	215	2.07	2.07	0.40	1	24	–	–	24	4.40	0.50	3.2
5	6	130	1.21	8.61	0.47	4	24	0.6		25	4.30	0.42	15.7

TABLE "C" DRAINAGE
UNDERGROUND STORM DRAINS
(OTHER THAN AIRFIELDS)

PIPE"n"0.012

DATE:JULY 1979 | SHEET 3 OF 3
PROJECT: COLUMBUS LTD
LOCATION:COLUMBUS. MS.
DESIGNED BY:W.O.P. | CHECKED BY:R.N.B.

DESIGN POINT: FROM INLET OR JUNCTION NUMBER	DESIGN POINT: TO INLET OR JUNCTION NUMBER	HYDRAULIC DESIGN DATA FOR STORM DRAIN: LENGTH (FT.)	DESIGN DISCHARGE CAPACITY (CFS) (COL.23)	SELECTED PIPE SIZE (IN.)	SLOPE IN FT./FT.	HEAD LOSS AT SECTION CHANGE: VELOCITY OF IN FLOW "V" (FPS)	LOSS COEFFICIENT "K" (FIG.XI)	HEAD LOSS $KV^2/2g$ (FT.)	CONSTRUCTION DATA: INVERT ELEVATION AT COL.29 (FT.)	INVERT ELEVATION AT COL.30 (FT.)	ELEVATION OF FINISHED GRADE AT COL.29	DEPTH OF COVER AT COL.29 (FT.)	DEPTH OF COVER MINIMUM IN LINE IF LOSS THAN COL.29(FT.)
29	30	31	32	33	34	35	36	37	38	39	40	41	42
1	2	170	3.3	12	0.0083	5.2	0.20	0.08	135.75	134.31	138.0	1.10	–
2	3	236	6.6	15	0.0100	6.6	0.20	0.14	133.98	131.62	137.5	2.11	–
3	8	200	10.0	18	0.0065	6.1	0.60	0.35	131.23	129.93	136.0	3.10	–
4	5	215	3.2	12	0.0085	5.2	0.60	0.25	132.26	130.43	137.0	3.59	–
5	6	130	15.7	24	0.0050	6.4	–	–	129.08	128.43	135.5	4.21	–

Exhibit 4–1

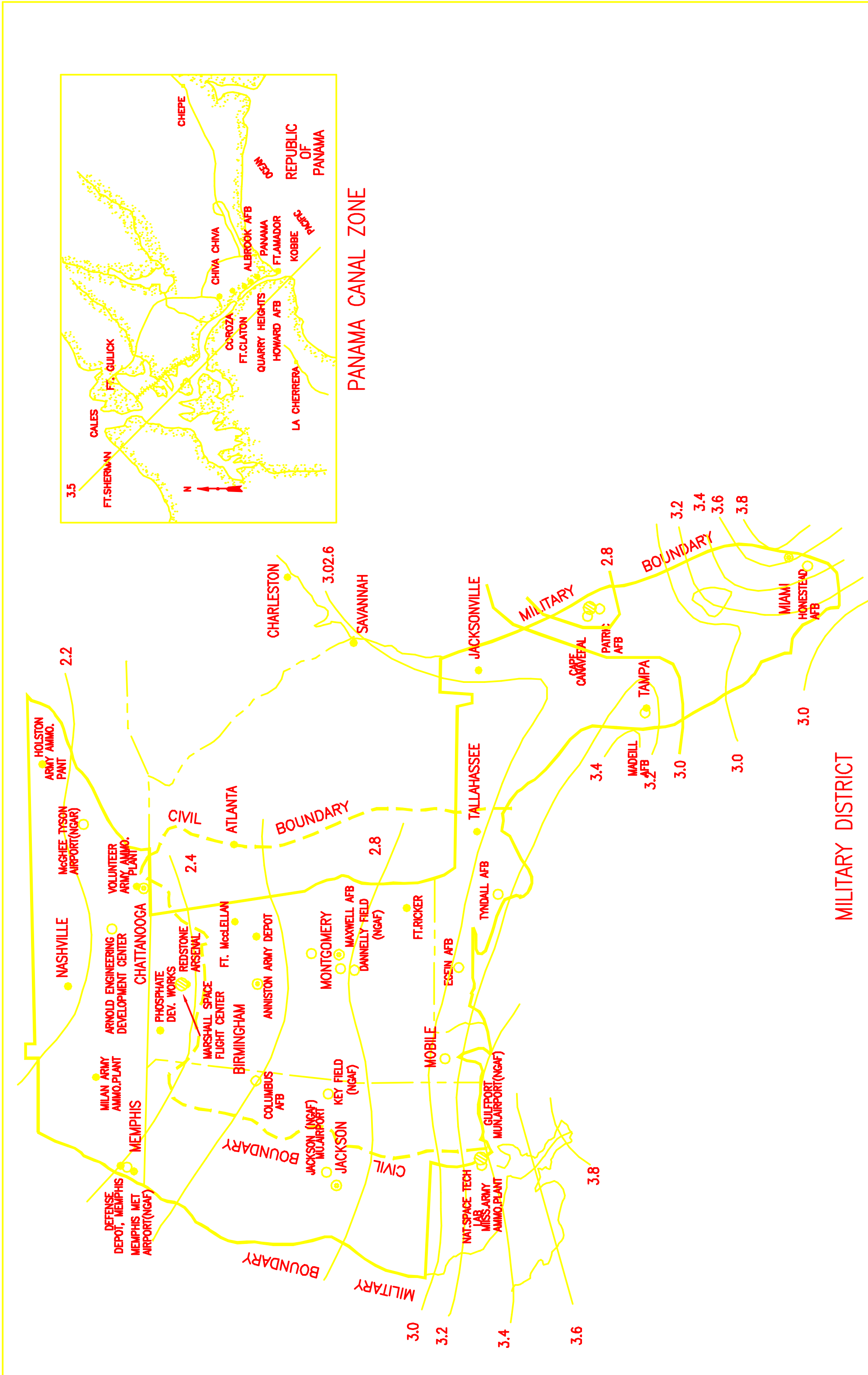


FIGURE I
DESIGN STORM INDEX
10 YEARS, 1-HOUR RAINFALL (INCHES)

Exhibit 4-2

TYPE OF SURFACE	"C"
ASPHALT PAVEMENT	0.90
CONCRETE PAVEMENT	0.90
GRAVEL OR MACADAM PAVEMENTS	0.35–0.70
IMPERVIOUS SOILS	0.40–0.65
IMPERVIOUS SOILS WITH TURF	0.30–0.55
SLIGHTLY PERVIOUS SOILS	0.15–0.40
SLIGHTLY PERVIOUS SOILS WITH TURF	0.10–0.30
PERVIOUS SOILS	0.01–0.10
WOODED AREAS (DEPENDING ON SURFACE SLOPE AND SOIL COVER)	0.01–0.20

EXAMPLE

FIGURE II
SURFACE RUNOFF COEFFICIENTS

TYPE OF SURFACE	"n"
SMOOTH PAVEMENT	0.02
DITCHES AND SWALES	0.02
COMPACTED GRAVEL SURFACES	0.06
BARE SURFACES	0.10
CHANNELIZED FLOW FROM AVERAGE GRASS COVER	0.20
SPARSE GRASS COVER	0.20
AVERAGE GRASS COVER	0.40
DENSE GRASS COVER	0.80

EXAMPLE

FIGURE III
RETARDENCE COEFFICIENTS

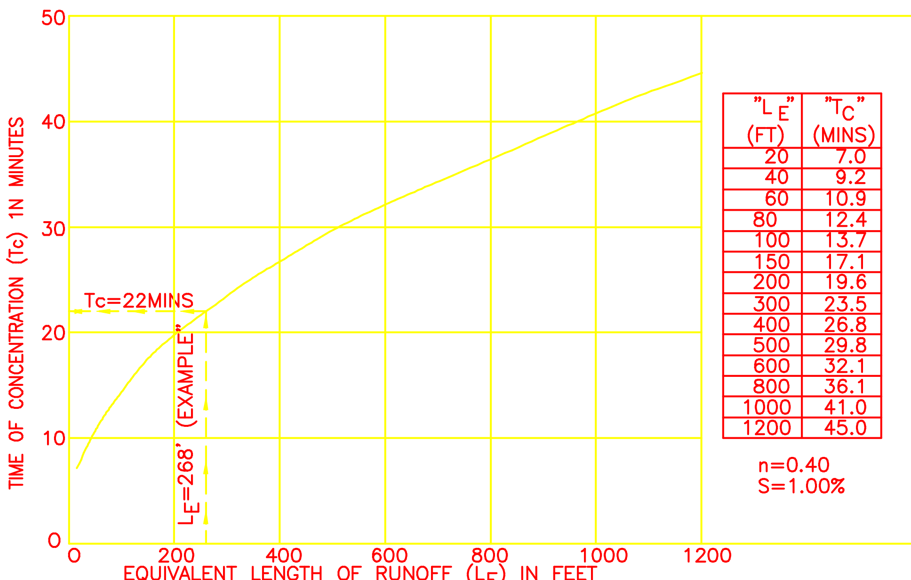
Exhibit 4–3

NOTE"
"D" – DENOTES DRAINED MATERIAL
"U" – DENOTES UNDRAINED MATERIAL

MAJOR DIVISIONS		LETTER	DENSE COVER	AVERAGE COVER	SPARSE (BARE) COVER
COARSE GRAINED	GRAVEL & GRAVELLY SOILS	GW	1.0–1.5	0.8–1.2	0.6–1.0
		GP	1.0–1.5	0.8–1.2	0.6–1.0
		GM "D"	0.6–0.8	0.4–0.6	0.2–0.4
		GM "U"	0.4–0.5	0.3–0.4	0.2–0.3
		GC	0.3–0.4	0.2–0.3	0.1–0.2
	SAND & SANDY SOILS	SW	1.0–1.5	0.8–1.2	0.6–1.0
		SP	1.0–1.5	0.8–1.2	0.6–1.0
		SM "D"	0.6–0.8	0.4–0.6	0.2–0.4
		SM "U"	0.4–0.5	0.3–0.4	0.2–0.3
		SC	0.3–0.4	0.2–0.3	0.1–0.2
FINE GRAINED	SILTS & CLAYS LL<50	CL	0.1–0.2	0.1–0.2	0.02–0.1
		ML	0.6–0.8	0.4–0.6	0.2–0.4
		OL	0.6–0.8	0.4–0.6	0.2–0.4
	SILTS & CLAYS LL>50	CH	0.1–0.2	0.1–0.2	0.02–0.1
		MH	0.6–0.8	$\boxed{0.4–0.6}$	$\boxed{0.2–0.4}$
		OH	0.1–0.2	0.1–0.2	0.02–0.1
ORGANIC SOILS		PT	0.6–0.8	0.4–0.6	0.2–0.4
PAVEMENTS				$\boxed{0.0}$	

EXAMPLE

FIGURE IV
INFILTRATION RATES "F" (INCHES/HOUR)



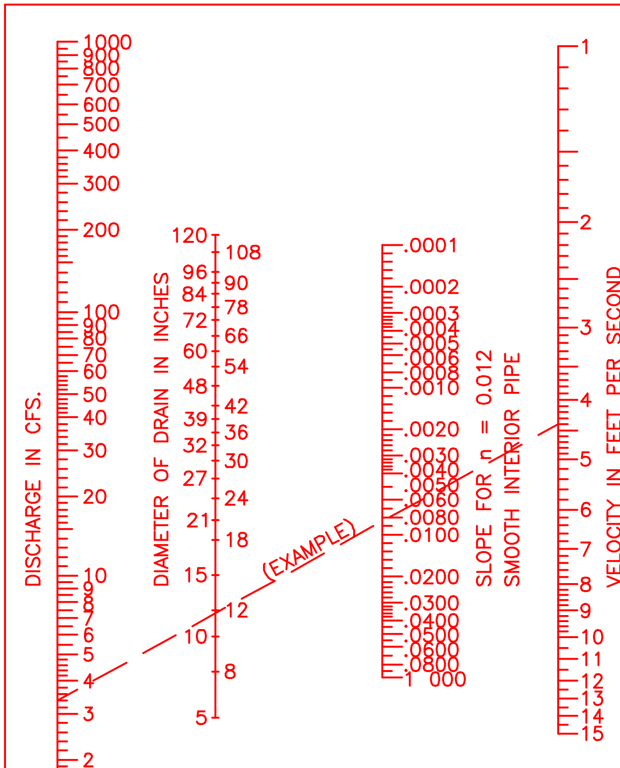
"L_E" (FT)	"T_C" (MINS)
20	7.0
40	9.2
60	10.9
80	12.4
100	13.7
150	17.1
200	19.6
300	23.5
400	26.8
500	29.8
600	32.1
800	36.1
1000	41.0
1200	45.0

FIGURE V
TIME OF CONCENTRATION

Exhibit 4–4

		EXAMPLE	DESIGN STORM INDEX					
Tc	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.6	3.8
10	5.55	5.85	6.25	6.60	6.95	7.30	7.60	7.90	8.25
11	5.35	5.70	6.05	6.35	6.70	7.10	7.40	7.70	8.00
12	5.15	5.50	5.85	6.15	6.50	6.90	7.20	7.50	7.80
13	5.00	5.35	5.70	6.00	6.35	6.75	7.00	7.30	7.60
14	4.85	5.20	5.55	5.85	6.15	6.50	6.80	7.10	7.40
15	4.75	5.05	5.40	5.70	6.00	6.35	6.60	6.95	7.20
16	4.60	4.90	5.25	5.55	5.90	6.20	6.45	6.80	7.05
17	4.50	4.80	5.10	5.45	5.75	6.10	6.30	6.65	6.90
18	4.35	4.65	5.00	5.30	5.60	5.95	6.15	6.50	6.75
19	4.25	4.50	4.85	5.15	5.50	5.85	6.05	6.35	6.60
20	4.15	4.45	4.75	5.05	5.40	5.70	5.95	6.25	6.50
21	4.05	4.35	4.65	4.95	5.25	5.60	5.85	6.15	6.40
EXAMPLE 22	4.00	4.25	4.60	4.85	5.15	5.50	5.75	6.05	6.30
23	3.90	4.20	4.50	4.80	5.05	5.40	5.65	5.95	6.20
24	3.85	4.10	4.40	4.70	5.00	5.30	5.55	5.85	6.10
25	3.75	4.05	4.30	4.60	4.90	5.20	5.45	5.75	6.00
26	3.65	3.95	4.25	4.55	4.80	5.10	5.35	5.65	5.90
27	3.60	3.85	4.15	4.45	4.75	5.00	5.25	5.55	5.80
28	3.55	3.80	4.10	4.35	4.65	4.95	5.15	5.45	5.70
29	3.45	3.75	4.00	4.30	4.55	4.85	5.10	5.35	5.65
30	3.40	3.65	3.95	4.25	4.50	4.75	5.05	5.30	5.60
31	3.35	3.60	3.85	4.15	4.45	4.70	4.95	5.20	5.50
32	3.30	3.55	3.80	4.10	4.35	4.60	4.85	5.10	5.40
33	3.25	3.50	3.75	4.00	4.30	4.55	4.75	5.00	5.30
34	3.20	3.45	3.70	3.95	4.20	4.45	4.70	4.95	5.20
35	3.15	3.40	3.65	3.90	4.15	4.40	4.65	4.90	5.15
36	3.10	3.35	3.60	3.85	4.10	4.35	4.55	4.80	5.05
37	3.05	3.30	3.50	3.75	4.00	4.30	4.50	4.70	4.95
38	3.00	3.25	3.45	3.70	3.95	4.25	4.45	4.65	4.90
39	2.95	3.20	3.40	3.65	3.90	4.20	4.40	4.60	4.85
40	2.90	3.15	3.35	3.60	3.85	4.15	4.35	4.55	4.80
45	2.70	2.90	3.15	3.35	3.60	3.85	4.05	4.25	4.50
50	2.50	2.70	2.95	3.15	3.40	3.60	3.80	4.05	4.20
55	2.35	2.55	2.75	2.95	3.20	3.40	3.60	3.80	4.05
60	2.20	2.40	2.60	2.80	3.00	3.20	3.40	3.60	3.80

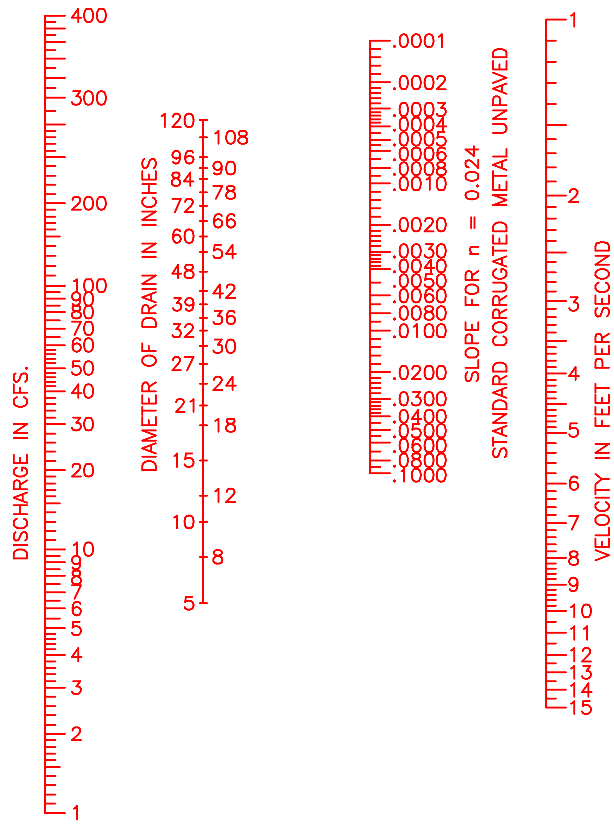
FIGURE VI
RAINFALL INTENSITY "I"



NOMOGRAPH FOR COMPUTING REQUIRED SIZE
OF CIRCULAR DRAIN
SMOOTH INTERIOR, FLOWING FULL
n = 0.012

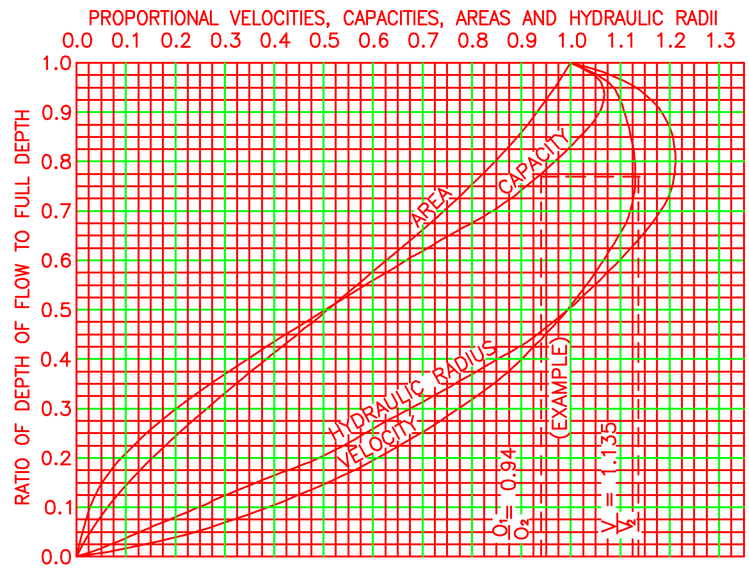
FIGURE VII

Exhibit 4–5



NOMOGRAPH FOR COMPUTING REQUIRED SIZE
OF CIRCULAR DRAIN
STANDARD CORRUGATED METAL PIPE UNPAVED
FLOWING FULL
n = 0.024

FIGURE VIII



$\frac{D}{d}$	$\frac{a}{A}$	$\frac{R_1}{R_2}$	$\frac{V_1}{V_2}$	$\frac{Q_1}{Q_2}$
0.025	0.00676	0.066	0.163	0.0011
0.050	0.01870	0.133	0.258	0.0048
0.100	0.05210	0.252	0.396	0.0207
0.150	0.09410	0.372	0.587	0.0490
0.200	0.14240	0.484	0.616	0.0876
0.300	0.25320	0.684	0.777	0.1959
0.400	0.37360	0.856	0.201	0.3365
0.500	0.50040	1.000	1.000	0.5000
0.600	0.62650	1.112	1.073	0.6722
0.700	0.74740	1.184	1.119	0.8362
0.750	0.80470	1.208	1.134	0.9122
0.800	0.85820	1.216	1.139	0.9775
0.850	0.90660	1.212	1.137	1.0301
0.900	0.94660	1.192	1.124	1.0657
0.950	0.98170	1.144	1.094	1.0732
0.970	0.99190	1.116	1.076	1.0670
0.980	0.99570	1.096	1.053	1.0583
0.990	0.99820	1.068	1.045	1.4100
1.000	1.00000	1.000	1.000	1.0000

LEGEND

- D – DEPTH OF FLOW
- d – DIAMETER OF CONDUIT
- A – CROSS-SECTIONAL AREA OF CONDUIT
- a – CROSS-SECTIONAL AREA OF SEGMENT
- R_1 – HYDRAULIC RADIUS OF SEGMENT
- R_2 – HYDRAULIC RADIUS OF CONDUIT FLOWING FULL
- V_1 – VELOCITY OF FLOW IN SEGMENT
- V_2 – VELOCITY OF FLOW IN CONDUIT FLOWING FULL
- Q_1 – CAPACITY AT PARTIAL DEPTH
- Q_2 – CAPACITY OF CONDUIT FLOWING FULL

HYDRAULIC ELEMENTS
CIRCULAR CONDUITS

BASED ON MANNINGS FORMULA

FIGURE IX

Exhibit 4–6

"n"=0.012 FOR SMOOTH INTERIOR PIPES OF ANY SIZE, SHAPE OR TYPE*

"n" VALUE FOR ANNULAR CORRUGATED METAL

CORRUGATION SIZE	
2 2/3 BY 1/2 INCH	0.024
3 BY 1 INCH	0.027
6 BY 2 INCH	0.028–0.033
9 BY 2 1/2 INCH	0.033

"n" VALUE FOR HELICAL CORRUGATED METAL (2 2/3 BY 1/2 INCH CORRUGATIONS)

PIPE DIAMETER	
12–18 INCHES	0.011–0.014
24–30 INCHES	0.016–0.018
36–96 INCHES	0.019–0.024

* INCLUDES BITUMINIZED FIBER, CAST IRON, CLAY, CONCRETE (PRECAST OR CAST-IN-PLACE) OR FULLY PAVED CORRUGATED METAL PIPE.

FIGURE X

ROUGHNESS COEFFICIENTS "n" FOR VARIOUS PIPE

TYPE OF JUNCTIONS	"K"
FOR NO BENDS AT JUNCTIONS	0.20
FOR BENDS AT JUNCTIONS OF 25 DEGREES	0.25
FOR BENDS AT JUNCTIONS OF 45 DEGREES	0.35
FOR BENDS AT JUNCTIONS OF 90 DEGREES	0.40
FOR JUNCTIONS OF THREE OR MORE PIPE	0.60

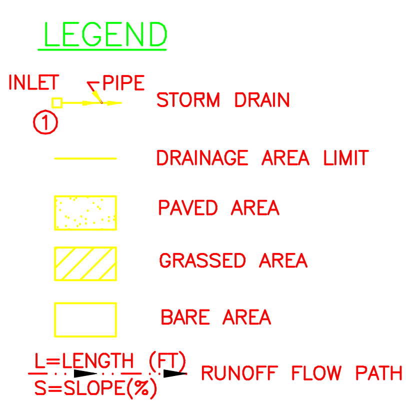
FIGURE XI

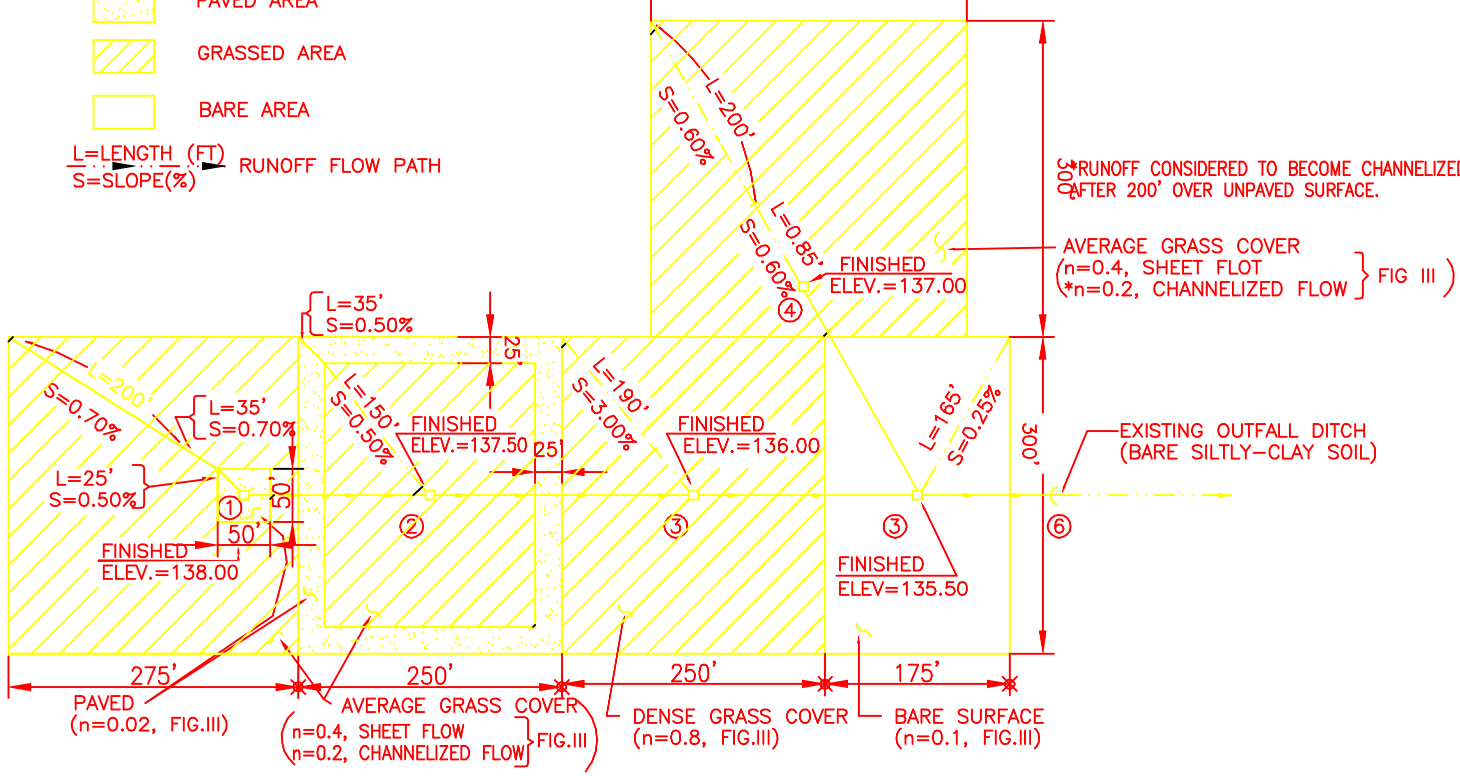
HEAD LOSS COEFFICIENTS AT JUNCTIONS

Exhibit 4–7

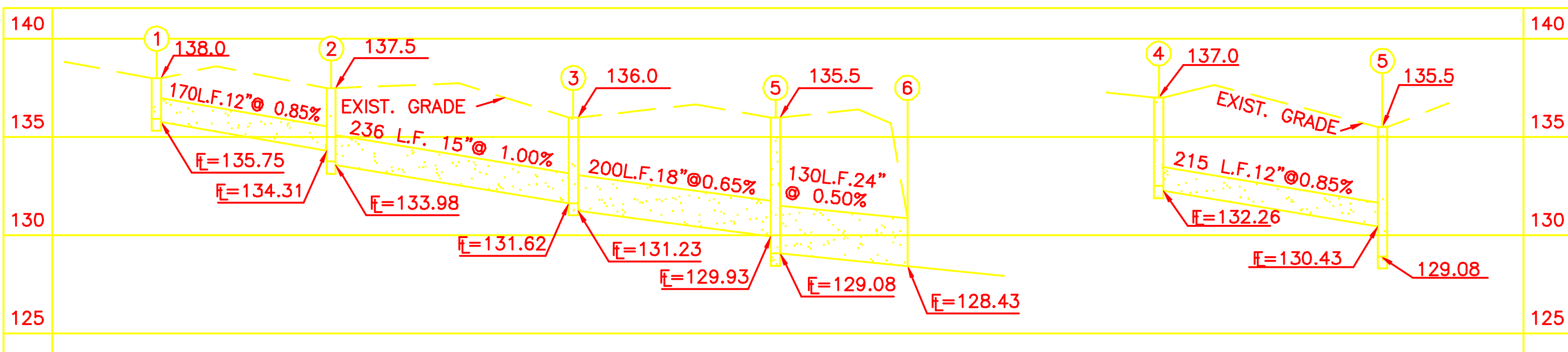
OVERALL PHYSICAL CHARACTERISTICS: THE OVERALL DRAINAGE AREA CONSISTS OF AVERAGE GRASSED, BARE SOIL AND ASPHALT PAVED AREAS. THE PREDOMINANT SOIL TYPE WITHIN THE OVERALL AREA IS AN IMPERVIOUS FINE GRAIN SILT CLASSIFIED AS MH. THESE GENERAL CHARACTERISTICS WERE USED TO DETERMINE THE COEFFICIENTS OF RUNOFF "C" FROM FIG. II AND INFILTRATION RATES "F" FROM FIG. IV. THE "C" AND "F" VALUES ARE SHOWN AT THE TOPS OF COLUMNS 2, 3 AND 4 OF TABLE "A".

LEGEND





PLAN — DESIGN EXAMPLE



PROFILE–DESIGN EXAMPLE

BIBLIOGRAPHY:

1. FIGURES VII AND VIII WERE TAKEN FROM TM 5–820–1. FIGURES 25 & 27 RESPECTIVELY, DATED APRIL 1977.
2. FIGURE IX WAS TAKEN FROM TM 5–820–4. FIGURE 10,DATED JULY 1965.
3. FIGURE X WAS TAKEN FROM TM 5–820–3. TABLE 2–1,DATED JANUARY 1978.
4. FIGURE XI WAS DERIVED FROM "HANDBOOK OF HYDRAULICS", FIFTH EDITION BY KING AND BRATER.

Exhibit 4–9

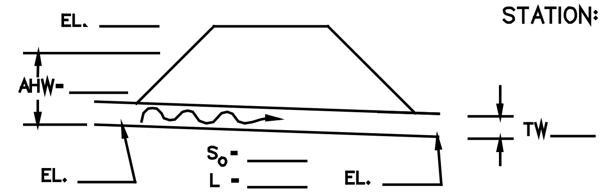
HYDRAULIC DESIGN DATA FOR CULVERTS (OTHER THAN AIRFIELDS)		
	DATE	SHEET OF
	PROJECT	
	LOCATION	
	DESIGNED BY	CHECKED BY

HYDRAULIC AND CHANNEL INFORMATION

Q= ________ TW= ________

Q FROM COLUMN 14 OF TABLE "A"

LOCATION: ________
STATION: ________



S_o = ____
L = ____

MEAN STREAM VELOCITY = ________
MAX. STREAM VELOCITY = ________

CULVERT DESCRIPTION (ENTRANCE TYPE)	Q (CFS)	SIZE (IN.)	HEADWATER COMPUTATION										CONTROLLING HW (FT)	OUTLET VELOCITY (FPS)	REMARKS
			INLET CONT.		OUTLET CONTROL HW = H + h_o - LS_o										
			$\frac{HW}{D}$	HW (FT)	Ke	H (FT)	d_c (FT)	$\frac{d_c + D}{2}$	TW (FT)	h_o (FT)	LS_o (FT)	HW (FT)			

SUMMARY AND RECOMMENDATIONS:

Exhibit 4-10

DESIGN STORM INDEX ________ IN./HR. (FIG. 1)
Q= CA (I-F) DESIGN STORM 10 YEAR
C= SURFACE RUNOFF COEFFICIENT I= INTENSITY
A= AREA (ACRES) F= INFILTRATION RATE

TABLE "A" DRAINAGE DRAIN INLET CAPACITIES (OTHER THAN AIRFIELDS)

DATE: SHEET OF
PROJECT:
LOCATION:
DESIGNED BY: CHECKED BY:

INLET NUMBER	DRAINAGE AREA (ACRES)			TOTAL AREA (COL. 2 + COL. 3 + COL. 4)	WEIGHTED "C"	EQUIVALENT LENGTH L_E				DRAIN INLET CAPACITY			
	PAVED	UNPAVED BARE	UNPAVED TURF			ACTUAL LENGTH "L" (FT.)	AVG. RETARD. "n"	AVG. SLOPE "S" %	EQUIV. LENGTH "L_E" (FORMULA 1) (FT.)	CRITICAL TIME T_c (FIG. V) (MIN.)	STORM INTENSITY "I" (FIG. VI)	WEIGHTED "F"	RATE OF SUPPLY "Q" (CFS)
	C=0.90	C=	C=										
	F=0.00	F=	F=										
1	2	3	4	5	6	7	8	9	10	11	12	13	14

Exhibit 4-11

TABLE "B" DRAINAGE
UNDERGROUND STORM DRAINS
(OTHER THAN AIRFIELDS)

DATE:	SHEET OF
PROJECT:	
LOCATION:	
DESIGNED BY:	CHECKED BY:

DESIGN POINT			DRAINAGE AERA			CRITICAL RUNOFF TIMETO PRODUCE MAX. FLOW IN DRAIN							
								DRAIN TIME					
FROM INLET OR JUNCTION NUMBER	TO INLET OR JUNCTION NUMBER	LENGTH (FT.)	INDIVIDUAL AREA (ACRES) (COL. 5)	ACCUM. TOTAL (ACRES)	WEIGHTED "C"	CRITICAL INLET NUMBER	CRITICAL INLET TIME T_c(MIN.) (COL. 11)	ASSUME PIPE VEL. 6 FPS (MIN.)	ACCUM. TOTAL (MIN.)	CRITICAL PIPE TIME T_c(MIN.) (COL. 22 + COL. 24)	STORM INTENSITY "I" (FIG. VI)	WEIGHTED "F"	RATE OF INFLOW INTO DRAINS (CFS)
15	16	17	18	19	20	21	22	23	24	25	26	27	28

Exhibit 4-12

TABLE "C" DRAINAGE
UNDERGROUND STORM DRAINS
(OTHER THAN AIRFIELDS)

DATE:	SHEET OF
PROJECT:	
LOCATION:	
DESIGNED BY:	CHECKED BY:

DESIGN POINT			HYDRAULIC DESIGN DATA FOR STORM DRAINS						CONSTRUCTION DATA				
						HEAD LOSS AT SECTION CHANGE			INVERT ELEVATION			DEPTH OF COVER	
FROM INLET OR JUNCTION NUMBER	TO INLET OR JUNCTION NUMBER	LENGTH (FT.)	DESIGN DISCHARGE CAPACITY (CFS) (COL. 28)	SELECTED PIPE SIZE (IN.)	SLOPE IN FT./FT.	VELOCITY OF INFLOW "V" (FPS)	LOSS COEFF. "K" (FIG. VI)	HEAD LOSS $KV^2/2g$ (FT.)	AT COL. 29 (FT.)	AT COL. 30 (FT.)	ELEV. OF FINISHED GRADE AT COL. 29	AT COL. 29 (FT.)	MINIMUM IN LINE IF LESS THAN COL. 29 (FT.)
29	30	31	32	33	34	35	36	37	38	39	40	41	42

Exhibit 4-13

STORM DRAINAGE PIPE AND STRUCTURE SCHEDULE

STRUCTURE			CONC. PIPE					C M PIPE						STRUCTURES			
		PIPE LGTH (FT.)			INVERT ELEV.		CLASS REINF. CONC.			INVERT ELEV.		GAUGE	CORR. SIZE				
FROM	TO		DIA (IN.)	SLOPE %	UP STREAM	DOWN STREAM		DIA (IN.)	SLOPE %	UP STREAM	DOWN STREAM			NO.	TYPE STR	TOP ELEV.	FIG. NO.

NOTE: FOR PIPE AND STRUCTURE MATERIAL REQUIREMENTS - SEE THE SPECIFICATIONS.

Exhibit 4-14